## Docket No.: 01997-282001/ MIT Case No. 8733

## WHAT IS CLAIMED IS:

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í	- 1	A composition	comprising.
	1.	A composition	comprising.

- 2 an inorganic particle,
- a linking group which has a distal end and a proximal end, the distal end being bound
- 4 to an outer surface of the inorganic particle and the proximal end including a first charged or
- 5 ionizable moiety, and
- a macromolecule having a second charged or ionizable moiety, wherein the first and
- 7 second charged or ionizable moieties electrostatically associate the inorganic particle with the
- 8 macromolecule to form an ionic conjugate.
- 1 2. The composition of claim 1, wherein the inorganic particle is a
- 2 semiconducting nanocrystal.
- The composition of claim 2, wherein the semiconductor nanocrystal includes
- a first semiconductor material selected from the group consisting of a Group II-VI
- 3 compound, a Group II-V compound, a Group III-VI compound, a Group III-V compound, a
- 4 Group IV-VI compound, a Group I-III-VI compound, a Group II-IV-VI compound, and a
- 5 Group II-IV-V compound.
- 1 4. The composition of claim 3, wherein the first semiconductor material is
- selected from the group consisting of ZnS, ZnSe, ZnTe, CdS, CdSe, CdTe, HgS, HgSe, HgTe,
- 3 AlN, AlP, AlAs, AlSb, GaN, GaP, GaAs, GaSb, GaSe, InN, InP, InAs, InSb, TlN, TlP, TlAs,
- 4 TISb. PbS. PbSe. PbTe, and mixtures thereof.
- The composition of claim 4, wherein the first semiconductor material is CdSe.
- 1 6. The composition of claim 5, wherein the first semiconductor material is
- 2 overcoated with a second semiconductor material.
- The composition of claim 6, wherein the second semiconductor material is
- ZnS, ZnO, ZnSe, ZnTe, CdS, CdO, CdSe, CdTe, MgS, MgSe, HgO, HgS, HgSe, HgTe, AlN,

- 3 AlP, AlAs, AlSb, GaN, GaP, GaAs, GaSb, GaSe, InN, InP, InAs, InSb, TlN, TlP, TlAs, TlSb,
- 4 PbS, PbSe, PbTe, SiO<sub>2</sub>, or mixtures thereof.
- 1 8. The composition of claim 1, wherein the inorganic particle further comprises a
- 2 plurality of linking groups each independently including a third charged or ionizable moiety.
- 1 9. The composition of claim 8 further comprising a plurality of macromolecules,
- each of the macromolecules including a fourth charged or ionizable moiety, wherein the
- 3 plurality of macromolecules are associated with the inorganic particle via electrostatic
- 4 interaction with the plurality of inorganic particle linking groups.
- 1 10. The composition of claim 1, wherein the inorganic particle comprises Ag, Au, or a phosphor.
- 1 11. The composition of claim 1, wherein the first charged or ionizable group
- 2 includes an hydroxide, alkoxide, carboxylate, sulfonate, phosphorate, or
- 3 quaternary ammonium.
- 1 12. The composition of claim 1, wherein the second charged or ionizable group
- 2 includes an hydroxide, alkoxide, carboxylate, sulfonate, phosphate, phosphonate, or
- 3 quaternary ammonium.
- 1 13. The composition of claim 1, wherein the linking group has the formula:
- $(R_1)_a-R_2-[(R_3)_b(R_4)_c]_d$
- 3 wherein
- R<sub>1</sub> is selected from the group consisting of C1-C100 heteroalkyl, C2-C100
- beteroalkenyl, heteroalkynyl, -OR, -SH, -NHR, -NR'R", -N(O)HR, -N(O)R'R", -PHR,
- 6 -PR'R", -P(NR'R")NR'R", -P(O)R'R", -P(O)(NR'R")NR'R", -P(O)(OR')OR", -P(O)OR,
- 7 -P(O)NR'R", -P(S)(OR')OR", and -P(S)OR, wherein R, R', R" are independently selected
- 8 from the group consisting of H, a branched or unbranched C1-C100 alkyl, a branched or
- 9 unbranched C2-C100 alkenyl, a branched or unbranched C2-C100 alkynyl, a branched or
- unbranched C1-C100 heteroalkyl, a branched or unbranched C2-C100 heteroalkenyl, a

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- branched or unbranched C2-C100 heteroalkynyl, with the proviso that when a is greater than 11 1 the R<sub>1</sub> groups can be attached to the R<sub>2</sub> or R<sub>3</sub> groups at the same or different atoms within 12
- those groups, the R<sub>1</sub> groups can be the same or different, or the R<sub>1</sub> groups can form a six, 13
- seven, eight, nine, or ten membered cycloalkyl, cycloalkenyl, thereocyclic, aryl, heteroaryl, 14
- or a six- to thirty-membered crown ether or heterocrown ether; 15
  - R<sub>2</sub> is selected from a bond, a branched or unbranched C2-C100 alkylene, a branched or unbranched C2-C100 alkenylene, a branched or unbranched C2-C100 heteroalkenylene, cycloalkyl, cycloalkenyl, cycloalkynyl, heterocyclic, aryl, and heteroaryl;
  - R<sub>3</sub> is selected from a branched or unbranched C2-C100 alkylene, a branched or unbranched C2-C100 alkenylene, a branched or unbranched C2-C100 heteroalkenylene, cycloalkyl, cycloalkenyl, cycloalkynyl, heterocyclic, aryl, and heteroaryl;
  - R<sub>4</sub> is selected from the group consisting of hydrogen, a carboxylate, a thiocarboxylate, an amide, a hydrazine, a sulfonate, a sulfoxide, a sulfone, a sulfite, a phosphate, a phosphonate, a phosphonium ion, an alcohol, a thiol, an amine, an ammonium, an alkyl ammonium, a nitrate; and
  - a is 1 to 40, b is 0 to 3, c is 1 to 30, d is 1 to 3, and when d is 2 or 3 the R<sub>3</sub> groups can be the same or different or can be linked together to form a five to ten members cycloalkyl, cycloalkenyl, heterocyclic, aryl, or heteroaryl.
  - The composition of claim 1, wherein the linking group has the formula 14.  $HS-C_2H_4-CH(SH)-(C_4H_8)-COOH.$
  - The composition of claim 1, wherein the macromolecule includes a 15. polypeptide or polynucleotide. 2
  - The composition of claim 15, wherein the macromolecule includes a 16. 1 polypeptide. 2
  - The composition of claim 16, wherein the second charged or ionizable moiety 17. 1 2 is a leucine zipper.

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- 1 18. The composition of claim 16, wherein the second charged or ionizable moiety 2 is polyaspartate.
- 1 19. The composition of claim 16, wherein the polypeptide includes a maltose 2 binding protein.
- 1 20. The composition of claim 16, wherein the polypeptide includes an 2 immunoglobulin G binding protein.
- 1 21. A composition comprising:
- 2 an inorganic particle,
  - a linking group which has a distal end and a proximal end, the distal end being bound to an outer surface of the inorganic particle and the proximal end including a first charged or ionizable moiety, and
  - a fusion protein including a second charged or ionizable moiety, wherein the first and second charged or ionizable moieties electrostatically associate the inorganic particle with the fusion protein to form an ionic conjugate.
- 1 22. The composition of claim 21, wherein the inorganic particle is a semiconducting nanocrystal.
- 1 23. The composition of claim 22, wherein the semiconductor nanocrystal includes
- a first semiconductor material selected from the group consisting of a Group II-VI
- 3 compound, a Group III-V compound, a Group III-VI compound, a Group III-V compound, a
- 4 Group IV-VI compound, a Group I-III-VI compound, a Group II-IV-VI compound, and a
- 5 Group II-IV-V compound.
- 1 24. The composition of claim 21, wherein the inorganic particle further comprises
- a plurality of linking groups each independently including a third charged or ionizable
- 3 moiety.

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- 25. The composition of claim 24 further comprising a plurality of 1 macromolecules, each of the macromolecules including a fourth charged or ionizable moiety, 2 wherein the plurality of macromolecules are associated with the inorganic particle via 3 electrostatic interaction with the plurality of inorganic particle linking groups. 4
- The composition of claim 21, wherein the inorganic particle comprises Ag, 26. 1 Au, or a phosphor. 2
- The composition of claim 21, wherein the first charged or ionizable group 27. 1 includes an hydroxide, alkoxide, carboxylate, sulfonate, phosphorate, or 2 quaternary ammonium. 3
  - The composition of claim 21, wherein the second charged or ionizable group 28. includes an hydroxide, alkoxide, carboxylate, sulfonate, phosphate, phosphonate, or quaternary ammonium.
    - The composition of claim 21, wherein the linking group has the formula: 29.  $(R_1)_a - R_2 - [(R_3)_b (R_4)_c]_d$

wherein

R<sub>1</sub> is selected from the group consisting of C1-C100 heteroalkyl, C2-C100 4 heteroalkenyl, heteroalkynyl, -OR, -SH, -NHR, -NR'R", -N(O)HR, -N(O)R'R", -PHR, 5 -PR'R'', -P(NR'R'')NR'R'', -P(O)R'R'', -P(O)(NR'R'')NR'R'', -P(O)(OR')OR'', -P(O)OR, -P(O)OR'', -6 -P(O)NR'R", -P(S)(OR')OR", and -P(S)OR, wherein R, R', R" are independently selected 7 from the group consisting of H, a branched or unbranched C1-C100 alkyl, a branched or 8 unbranched C2-C100 alkenyl, a branched or unbranched C2-C100 alkynyl, a branched or 9 unbranched C1-C100 heteroalkyl, a branched or unbranched C2-C100 heteroalkenyl, a 10 branched or unbranched C2-C100 heteroalkynyl, with the proviso that when a is greater than 11 1 the R<sub>1</sub> groups can be attached to the R<sub>2</sub> or R<sub>3</sub> groups at the same or different atoms within 12 those groups, the R<sub>1</sub> groups can be the same or different, or the R<sub>1</sub> groups can form a six, 13 seven, eight, nine, or ten membered cycloalkyl, cycloalkenyl, thereocyclic, aryl, heteroaryl, 14 or a six- to thirty-membered crown ether or heterocrown ether;

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- 16 R<sub>2</sub> is selected from a bond, a branched or unbranched C2-C100 alkylene, a branched 17 or unbranched C2-C100 alkenylene, a branched or unbranched C2-C100 heteroalkenylene, 18 cycloalkyl, cycloalkenyl, cycloalkynyl, heterocyclic, aryl, and heteroaryl;
- 19 R<sub>3</sub> is selected from a branched or unbranched C2-C100 alkylene, a branched or unbranched C2-C100 alkenylene, a branched or unbranched C2-C100 heteroalkenylene, cycloalkyl, cycloalkynyl, heterocyclic, aryl, and heteroaryl;
- R<sub>4</sub> is selected from the group consisting of hydrogen, a carboxylate, a thiocarboxylate, an amide, a hydrazine, a sulfonate, a sulfoxide, a sulfone, a sulfite, a phosphate, a phosphonate, a phosphonium ion, an alcohol, a thiol, an amine, an ammonium, an alkyl ammonium, a nitrate; and
- a is 1 to 40, b is 0 to 3, c is 1 to 30, d is 1 to 3, and when d is 2 or 3 the R<sub>3</sub> groups can be the same or different or can be linked together to form a five to ten members cycloalkyl, cycloalkenyl, heterocyclic, aryl, or heteroaryl.
- 1 30. The composition of claim 21, wherein the linking group has the formula 2 HS-C<sub>2</sub>H<sub>4</sub>-CH(SH)-(C<sub>4</sub>H<sub>8</sub>)-COOH.
  - 31. The composition of claim 21, wherein the second charged or ionizable moiety is a leucine zipper.
  - 32. The composition of claim 21, wherein the second charged or ionizable moiety is polyaspartate.
- 1 33. The composition of claim 21, wherein the fusion protein includes a maltose binding protein.
- 1 34. The composition of claim 21, wherein the fusion protein includes an immunoglobulin G binding protein.
  - 35. A method of forming an ionic conjugate, comprising:

- providing an inorganic particle including a linking group having a distal end and a 2 proximal end, the distal end being bound to an outer surface of the inorganic particle and the 3 proximal end including a first charged or ionizable moiety; and 4
- contacting a macromolecule having a second charged or ionizable moiety with the 5 inorganic particle, wherein the first and second charged or ionizable moieties electrostatically 6 associate the inorganic particle with the macromolecule to form an ionic conjugate. 7
- The method of claim 35, wherein the inorganic particle is a semiconducting 36. 1 nanocrystal. 2
- The method of claim 36, wherein the semiconductor nanocrystal includes a 37. 1 first semiconductor material selected from the group consisting of a Group II-VI compound, 2 a Group II-V compound, a Group III-VI compound, a Group III-V compound, a Group IV-3 VI compound, a Group II-IVI compound, a Group II-IV-VI compound, and a Group II-IV-4 V compound. 5
- The method of claim 37, wherein the first semiconductor material is selected 38. from the group consisting of ZnS, ZnSe, ZnTe, CdS, CdSe, CdTe, HgS, HgSe, HgTe, AlN, 2 AlP, AlAs, AlSb, GaN, GaP, GaAs, GaSb, GaSe, InN, InP, InAs, InSb, TlN, TlP, TlAs, TlSb, 3 PbS, PbSe, PbTe, and mixtures thereof. 4
  - The method of claim 38, wherein the first semiconductor material is CdSe. 39.
- The method of claim 39, wherein the first semiconductor material is 40. 1 overcoated with a second semiconductor material. 2
- The method of claim 40, wherein the second semiconductor material is ZnS, 41. 1
- ZnO, ZnSe, ZnTe, CdS, CdO, CdSe, CdTe, MgS, MgSe, HgO, HgS, HgSe, HgTe, AlN, AlP, 2
- AlAs, AlSb, GaN, GaP, GaAs, GaSb, GaSe, InN, InP, InAs, InSb, TlN, TlP, TlAs, TlSb, PbS, 3
- PbSe, PbTe, SiO<sub>2</sub>, or mixtures thereof. 4

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1	42.	The method of claim 35, wherein the inorganic particle further comprises a
2	plurality of li	nking groups each independently including a third charged or ionizable moiety

- 1 43. The method of claim 35 further comprising a plurality of macromolecules, 2 each of the macromolecules including a fourth charged or ionizable moiety, wherein the 3 plurality of macromolecules are associated with the inorganic particle via electrostatic 4 interaction with the plurality of inorganic particle linking groups.
- 1 44. The method of claim 35, wherein the inorganic particle comprises Ag, Au, or 2 a phosphor.
  - 45. The method of claim 35, wherein the first charged or ionizable group includes a hydroxide, alkoxide, carboxylate, sulfonate, phosphate, phosphonate, or quaternary ammonium.
  - 46. The method of claim 35, wherein the second charged or ionizable group includes an hydroxide, alkoxide, carboxylate, sulfonate, phosphonate, or quaternary ammonium.
  - 47. The method of claim 35, wherein the linking group has the formula:  $(R_1)_a R_2 [(R_3)_b (R_4)_c]_d$

3 wherein

4 R<sub>1</sub> is selected from the group consisting of C1-C100 heteroalkyl, C2-C100

5 heteroalkenyl, heteroalkynyl, -OR, -SH, -NHR, -NR'R", -N(O)HR, -N(O)R'R", -PHR, -

6 PR'R", -P(NR'R")NR'R", P(O)R'R", P(O)(NR'R")NR'R", -P(O)(OR')OR", P(O)OR,

7 P(O)NR'R", -P(S)(OR')OR", and P(S)OR, wherein R, R', R" are independently selected from

8 the group consisting of H, a branched or unbranched C1-C100 alkyl, a branched or

9 unbranched C2-C100 alkenyl, a branched or unbranched C2-C100 alkynyl, a branched or

unbranched C1-C100 heteroalkyl, a branched or unbranched C2-C100 heteroalkenyl, a

branched or unbranched C2-C100 heteroalkynyl, with the proviso that when a is greater than

12 1 the R<sub>1</sub> groups can be attached to the R<sub>2</sub> or R<sub>3</sub> groups at the same or different atoms within

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- those groups, the R<sub>1</sub> groups can be the same or different, or the R<sub>1</sub> groups can form a six, 13 seven, eight, nine, or ten membered cycloalkyl, cycloalkenyl, thereocyclic, aryl, heteroaryl, 14 or a six- to thirty-membered crown ether or heterocrown ether; 15
- $R_2$  is selected from a bond (i.e.,  $R_2$  is absent in which case  $R_1$  attaches to  $R_3$ ), a 16 branched or unbranched C2-C100 alkylene, a branched or unbranched C2-C100 alkenylene, 17 a branched or unbranched C2-C100 heteroalkenylene, cycloalkyl, cycloalkenyl, 18 cycloalkynyl, heterocyclic, aryl, and heteroaryl; 19
  - R<sub>3</sub> is selected from a branched or unbranched C2-C100 alkylene, a branched or unbranched C2-C100 alkenylene, a branched or unbranched C2-C100 heteroalkenylene, cycloalkyl, cycloalkenyl, cycloalkynyl, heterocyclic, aryl, and heteroaryl;
    - R<sub>4</sub> is selected from the group consisting of hydrogen, a carboxylate, a thiocarboxylate, and amid, an amine, a hydrazine, a sulfonate, a sulfoxide, a sulfone, a sulfite, a phosphate, a phosphonate, a phosphonium ion, an alcohol, a thiol, an amine, an ammonium, an alkyl ammonium, a nitrate; and
    - a is 1 to 4, b is 0 to 3, c is 1 to 3, d is 1 to 3, and when d is 2 or 3 the R<sub>3</sub> groups can be the same or different or can be linked together to form a five to ten members cycloalkyl, cycloalkenyl, heterocyclic, aryl, or heteroaryl.
  - The method of claim 35, wherein the linking group has the formula 48.  $HS-C_2H_4-CH(SH)-(C_4H_8)-COOH.$ 2
  - The method of claim 35, wherein the macromolecule includes a polypeptide 49. 1 or a polynucleotide. 2
  - The method of claim 49, wherein the macromolecule includes a polypeptide. 50. 1
  - The method of claim 50, wherein the second charged or ionizable moiety is a 51. 1 leucine zipper. 2
  - The method of claim 50, wherein the second charged or ionizable moiety is 52. 1 2 polyaspartate.

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1	53.	The method of claim 50, wherein the polypeptide includes a maltose binding
2	protein.	

- 1 54. The method of claim 50, wherein the polypeptide includes an immunoglobulin 2 G binding protein.
- The method of claim 35 further including forming the macromolecule by recombinant methods.
- The method of claim 35 further including forming the macromolecule by synthetic methods.
  - 57. A method of detecting the presence of a predetermined species in a solution, comprising:
  - contacting a solution with an ionic conjugate, wherein the ionic conjugate includes an inorganic particle electrostatically associated with a macromolecule, the macromolecule capable of binding specifically to the predetermined species.
  - 58. The method of claim 57 further comprising forming an ionic conjugate by adding an inorganic particle and a macromolecule to the solution, wherein the inorganic particle includes a linking group having a distal end and a proximal end, the distal end being bound to an outer surface of the inorganic particle and the proximal end including a first charged or ionizable moiety and the macromolecule includes a second charged or ionizable moiety, the first and second charged or ionizable moieties associating electrostatically to